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Implementation and Optimization of Server Room Temperature and Humidity Control System using Fuzzy Logic Based on Microcontroller

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Abstract. Server room is a room used to put network devices and server computers that contain important and valuable data for the company, especially for companies or institute that already implement IT technology in its operational activities. Server room should always be monitored at all times. In this research we do the implementation and optimization on the design that we have successfully made in our previous research, as well as to test the speed and effectiveness of fuzzy control system in controlling the temperature and humidity of server room. In this research, the optimized system is able to control the temperature from 26.2C to 22.1C in 23 minutes and able to control the humidity from 67.6% to 55.3% in 6 minutes. The system is also able to keep the server room temperature in the range of normal values required with the highest temperature is 23C, the lowest temperature 21C and the average temperature is 21.7905C. While on the humidity test, system is enough to control the server room humidity in the range of normal values required. During the 24 hours of humidity monitoring, only 8 times the increase of humidity happened with an average increase value 0.65%, the highest humidity 61.4%, and the average time until the humidity returned to the standard value is 50.125 seconds, with the longest time 168 seconds and the fastest is 17 seconds. The lowest humidity value obtained is 45.9% and the average humidity is 52.44320017%. The system is also capable to send data from the microcontroller to the web server database until the data is displayed on the web page with an average delay time 0.636363636 seconds and able to send early warning notification in realtime via twiter with the average delay time of sending data from web application monitoring to twitter 0.9 seconds.

1. Introduction

Server room is a room that is used to put network devices and server computers that contain important and valuable data for the company, especially for companies or institute that already implement IT technology in its operational activities. Therefore this room should always be monitored at all times[1]. One way to monitoring the server room is to use internet of things (IoT) based monitoring system that is the concept where server room conditions can be monitored by using a tool that capable to transferring data of server room conditions over the Internet without need for interaction between humans and humans or interaction between humans with computer [2]. One important factor that must be monitored on server room is the temperature and humidity, where the standard temperature for server room in Indonesia is 21-23C (70-74F), while the standard humidity for server room in Indonesia is 45% to 60% [3]. However, monitoring of temperature and humidity conditions is not yet effective enough to ensure that the temperature and humidity conditions are always in normal condition, a control system is needed to regulate the temperature and humidity of the server room to prevent the computers and networks equipment becomes hot and so that eventually shutdown if temperature is too hot or can cause excessive static electricity if humidity is low or to prevent corrosion [3] and short circuit [4] while humidity is too high.

Some previous research have discussed about the control of temperature and humidity of the room by controlling the speed of the fan and compressor in the air conditioner [5][6]. In other research, researcher are using lights, ekhaust fan, water pump to control the climate in a room[7]. However, research [5][6][7] still discusses temperature and humidity control in a general room. While some research that focus on temperature and humidity control in the server room not using fuzzy logic as a controlling algorithm and only do the control by turning on and off equipment using relay [8]. Other research is still limited to monitoring and sending notifications and early warning message via email[9].

This research is a continuation of the research we have done before. In previous research, we have successfully designed a control system of temperature and humidity of the server room using IoT-based sensor and microcontroller with fuzzy logic control algorithm with fuzzy type is mamdani[10]. Microcontroller based fuzzy logic is designed to be able to control the air conditioner to control the temperature and use the dry mode to reduce the humidity in the server room [11] by controlling the air conditioner using infrared remote control. This previous research is limited to system design and simulation of temperature and humidity control using fuzzy logic that is an appropriate way to map an input space to the output space[12] using Matlab FIS Editor [10][13]. In this research we do the implementation and optimization on the design that we have successfully made in previous research, as well as to test the speed and effectiveness of fuzzy control system in controlling the temperature and humidity of server room.

2. Methodology

In this section we discuss how the server room temperature and humidity control system using fuzzy logic based on microcontroller can work and what are the optimizations we do. In the early step, the fuzzy logic control system will perform temperature and humidity readings using the DHT22 sensor, and AC voltage data readings using the ZMPT101B sensor. We use DHT22 because DHT22 is a digital sensor and its accuracy is better than DHT11[14][15]. Then all data is uploaded to the database on the online server via HTTP Protocol because this protocol is easy to implemented and fairly fast response to send data[16]. The data then displayed on the web-based monitoring application page. If the data is not appropriate or not in normal conditions that required for server room then the system will show notification in web application and send notification via twitter to the admin or officer where the delivery of notification messages via twitter faster than email[17]. While the control process is done by analyzing the temperature and humidity data. If the temperature and humidity are in normal condition then the system will repeat the reading of temperature and humidity data. The reading of data is done in the span of time every 30 second. In this research we not only use fuzzy to show the status of the room condition[18], system also designed to control the devices used to control temperature and humidity[19][20]. This system is designed to be able to control the Air Conditioner[21]. If temperature and humidity data are obtained in abnormal condition while reading temperature and humidity data then the system will activate fuzzy logic control, then fuzzy logic control will control the temperature and humidity by controlling the air conditioner by regulating the temperature and COOL or DRY operating mode as shown in the flowchart in Figure 1.

At the time of system implementation, we replaced the IR transmitter with Universal Air Conditioner Remote Control, this is done so that the system can be used universally on various types of Air Conditioner brand, In addition the use of IR Transmitter requires quite a lot of code lines and requires large enough memory and can only be used on certain AC types according to the code defined before. The IR transmitter connection to the AC device is also often not responded by the AC so we make changes to the previous hardware design by adding universal AC remote components and relays, as well as the addition of buzzer used to issue the notification sound. The design of the optimized hardware block diagram is shown in Figure 2 and the microcontroller based temperature and humidity control system wiring diagram is shown in Figure 3.

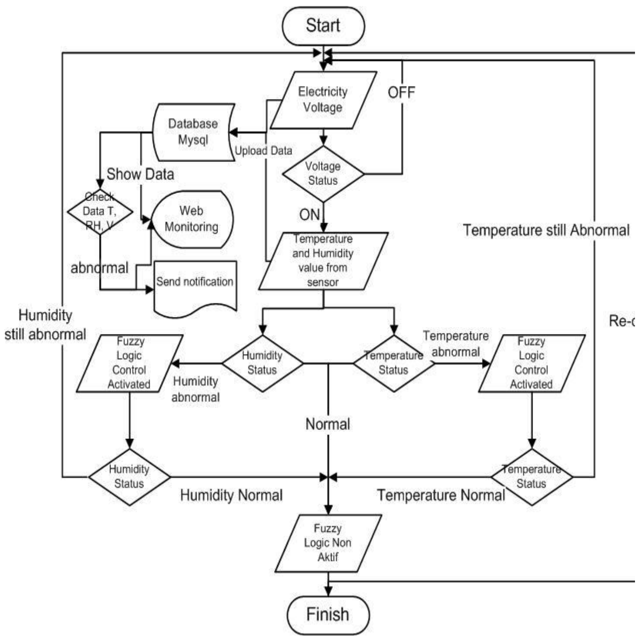

Figure 1. Flowchart of fuzzy logic control and monitoring system.

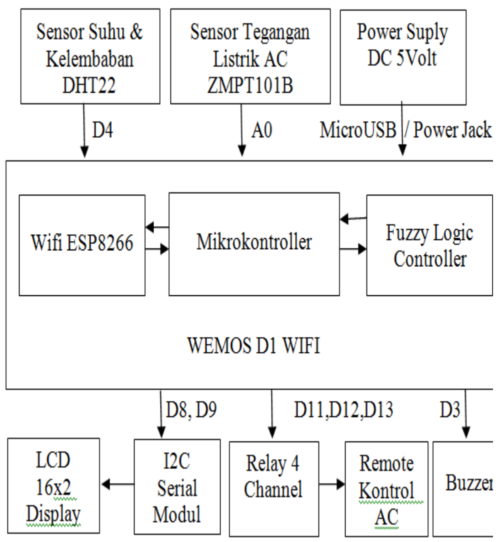

Figure 2. Block diagram of system control.

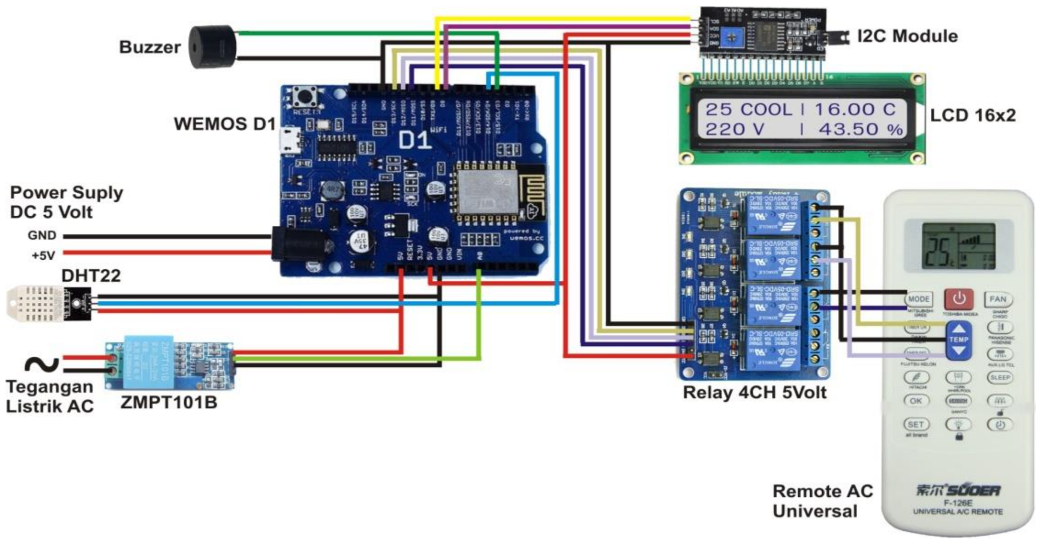

Figure 3. Design hardware and wiring of system control.

In this research we also do optimization on fuzzy membership function and rule base. This is done based on test results using the fuzzy membership function and rule basis in previous research, where the fuzzy output for AC controller Mode to set the humidity consists only 2 membership functions ie COOL and DRY as shown in Figure 4.

In a trial conducted in the server room of one of the college in Bengkulu obtained the result that the system with the configuration as in previous research has not been able to control the temperature and humidity. Figure 5 shows that the temperature is still above the maximum value of the standard temperature required for server room. While the use of AC Mode control only with 2 membership functions cause when the humidity is high, AC Mode is in DRY position then when humidity has reached 60% AC Mode will be changed to COOL mode. But evidently COOL mode was not able to keep the humidity to stay below 60%. When the humidity is in the 58-59% range, the humidity rises again above 60% so the AC Mode is changed back into DRY to lower the humidity again, and this happens continuously every 5 minutes as shown in Figure 6.

To solve this problem we added a new membership function on output variable ac-mode that is NORMAL membership function. This membership function is used to allow time delay so that when humidity drops below 60%, membership function of AC Mode changed in normal mode where the sistem did not make any changes on setting and still in DRY mode and persists until if humidity reaches under 45%, then AC mode is converted to COOL mode to raise the humidity. So the fuzzy ac-mode membership function becomes 3 pieces as shown in Figure 7.

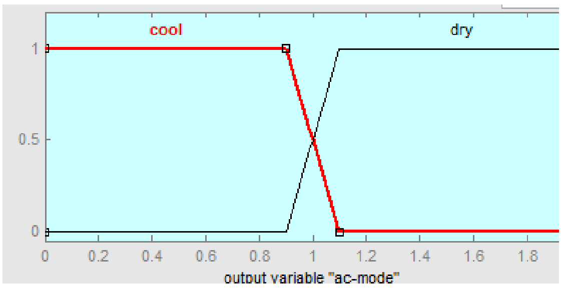

Figure 4. Previous configuration of output variable ac mode membership function.

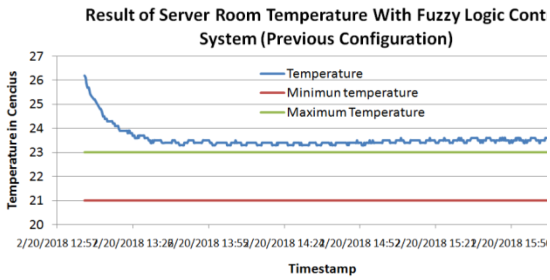

Figure 5. Result of server room temperature with fuzzy logic control system (Previous Configuration).

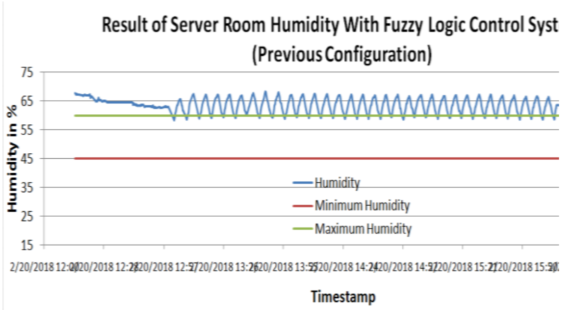

Figure 6. Result of server room humidity with fuzzy logic control system (Previous Configuration).

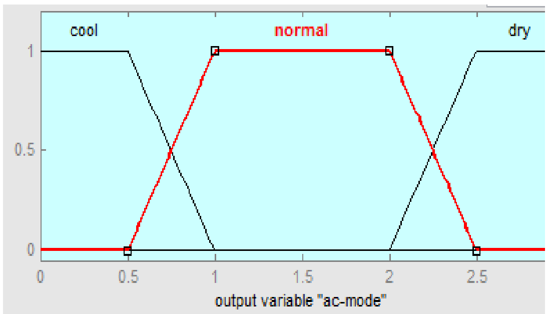

Figure 7. Optimized configuration of output variable ac mode membership function.

Addition to the fuzzy ac-mode membership function also changing the fuzzy rule base by adding a normal ac-mode membership function on the rule base so that the rule base has 2 variable inputs with each having 3 fuzzy membership. Variable temperature has fuzzy membership COOL, NORMAL and HOT. Variable humidity has fuzzy membership DRY, NORMAL and WET. Then by using the 9 rule base produced fuzzy AC Temperature output with 3 fuzzy membership ie LOW, MIDDLE, HIGH, and AC Mode are also divided into 3 fuzzy membership ie COOL, NORMAL and DRY. Where the rules used are as follows :

IF Temperature COOL AND Humidity DRY THEN Temperature AC HIGH AND AC Mode COOL

IF Temperature COOL AND Humidity NORMAL THEN Temperature AC HIGH AND AC Mode NORMAL

IF Temperature COOL AND Humidity WET THEN Temperature AC HIGH AND AC Mode DRY

IF Temperature NORMAL AND Humidity DRY THEN Temperature AC MIDDLE AND AC Mode COOL

IF Temperature NORMAL AND Humidity NORMAL THEN Temperature AC MIDDLE AND AC Mode NORMAL

IF Temperature NORMAL AND Humidity WET THEN Temperature AC MIDDLE AND AC Mode DRY

IF Temperature HOT AND Humidity DRY THEN Temperature AC LOW AND AC Mode COOL

IF Temperature HOT AND Humidity NORMAL THEN Temperature AC LOW AND AC Mode NORMAL

IF Temperature HOT AND Humidity WET THEN Temperature AC LOW AND AC Mode DRY

Then we re-tested the system using the optimized configuration with the fuzzy membership value for each fuzzy membership function as follows :

Fuzzy membership value for Input Fuzzy Temperature :
FuzzySet cool = (0, 0, 15, 21)
FuzzySet tnormal = (15, 21, 22, 26)
FuzzySet hot = (21, 26, 100, 100)

Fuzzy membership value for Input Fuzzy Humidity :
FuzzySet dry = (0, 0, 46, 50)
FuzzySet hnormal = (46, 50, 55, 59)
FuzzySet wet = (55, 59, 100, 100)

Fuzzy membership value for Input Fuzzy AC Temperature :
FuzzySet low = (16, 16, 20, 21)
FuzzySet middle = (20, 21, 23, 24)
FuzzySet high = (23, 24, 27, 27)

Fuzzy membership value for Input Fuzzy AC Mode :
FuzzySet accool = (0, 0, 0.5, 1)
FuzzySet acnormal = (0.5, 1, 2, 2.5)
FuzzySet acdry = (2, 2.5, 3, 3)

3. Result and Discussion

In this section we discuss the results of the tests we have done on the server room temperature and humidity control system using fuzzy logic based on microcontroller that was optimized in design, fuzzy membership and rule base. Testing is done in the server room of one of the college in Bengkulu with server room floor area 6M2 and volume of server room 18M3 with 3M length, 2M width and 3M height. The server room has no raised floor and consists of 4 PC servers. Air conditioning system using 2 unit of AC Split Panasonic CS-PC9NKJ 1PK that are used interchangeably. The position of the server room is located on the top floor of the building located on the edge of the building that make the server room wall exposed to direct sunlight.

So the temperature in the server room is often unstable. In addition, the humidity in the server room is also influenced by the location of the college which only 2 KM from the beach, so it has a high humidity that makes equipment and goods made of iron easy to rust.

3.1. Result of Temperature and Humidity Reading Test on DHT22 Sensor

DHT22 sensor reading test to measure the temperature and humidity is done by turning on the system, then record the results displayed on the LCD Display, then the DHT22 sensor readings value compared with the value of temperature and humidity that measured using HTC-2 Hygrometer tool. From 19 times DHT22 sensor reading test compared to HTC-2 Hygrometer result, obtained result as shown in Table 1 that temperature readings have average deviation value 0,394736842 degree Celcius and result of humidity reading have average deviation value 1,273684%.

Table 1. Result of temperature and humidity reading test DHT22 sensor and calibration with digital hygrometer HTC-2

Timestamp	Temperature		Temperature Deviation	Humidity		Humidity Deviation
	Wemos D1+DHT22	HTC-2		Wemos D1+DHT22	HTC-2	
2/24/2018 2:31	33	33.0	0	67.7	67	0.7
2/24/2018 2:32	31	29.9	1.1	65.3	66	0.7
2/24/2018 2:33	30.9	29.9	1	65.4	65	0.4
2/24/2018 2:34	28	27.1	0.9	63.5	62	1.5
2/24/2018 2:35	27.6	27.1	0.5	62.9	62	0.9
2/24/2018 2:36	27.4	26.5	0.9	57.3	55	2.3
2/24/2018 2:37	27	26.2	0.8	56	55	1
2/24/2018 2:38	26	26.1	0.1	53	51	2
2/24/2018 2:39	26	25.6	0.4	52.4	50	2.4
2/24/2018 2:40	23.1	23	0.1	45.1	44	1.1
2/24/2018 2:41	23.7	23.7	0	46	45	1
2/24/2018 2:42	23	22.9	0.1	46.2	45	1.2
2/24/2018 2:43	23.7	23.8	0.1	47.1	46	1.1
2/24/2018 2:44	24.1	24.4	0.3	48.2	47	1.2
2/24/2018 2:45	24.2	24.6	0.4	49.3	48	1.3
2/24/2018 2:46	24.5	24.8	0.3	50	49	1
2/24/2018 2:47	24.7	24.9	0.2	51.1	50	1.1
2/24/2018 2:48	25.4	25.5	0.1	54.6	53	1.6
2/24/2018 2:49	25.7	25.5	0.2	55.7	54	1.7
Average Temperature Deviation			0.394736842	Average Humitidy Deviation		1.273684

3.2. Result of Infrared Remote Control Command Test

Infrared remote control testing is done to see if the microcontroller can control the settings on the remote control as desired. The test is done by turn on the system and the remote control then view and record whether the settings value on the remote control in accordance with the settings value on the microcontroller. From the test results obtained that 100% microcontroller or system capable to controlling the control function on the remote control well as shown in Table 2.

Table 2. Result of testing command from microcontroller to infrared remote control

Timestamp	Temperature	Humidity	Temp AC Wemos D1	Temp AC Remote	Mode AC Wemos D1	Mode AC Remote
2/24/2018 9:21	33.4	66.7	18	18	DRY	DRY
2/24/2018 9:40	24.9	54.9	19	19	DRY	DRY
2/24/2018 9:47	23.3	49.8	20	20	DRY	DRY
2/24/2018 10:07	21.5	47	21	21	DRY	DRY
2/24/2018 10:20	22.2	58.2	20	20	DRY	DRY
2/24/2018 10:27	21.9	48.9	21	21	DRY	DRY
2/24/2018 10:41	22.2	58.9	20	20	DRY	DRY
2/24/2018 10:46	22.1	51.5	21	21	DRY	DRY
2/24/2018 11:04	21	48.6	22	22	DRY	DRY
2/24/2018 11:21	20.9	46.3	22	22	COOL	COOL
2/24/2018 11:24	21.1	58.5	21	21	COOL	COOL
2/24/2018 11:24	21.1	59.4	21	21	DRY	DRY
2/24/2018 11:28	22	58.2	20	20	DRY	DRY
2/24/2018 11:32	22.1	51.4	21	21	DRY	DRY

3.3. Result of Data Uploading Test from Microcontroller to Web Application

Testing upload data from microcontroller to the database server and web based monitoring application is done by connecting the device to the computer using a USB cable, and connecting the microcontroller to the internet using Wireless Access Point. Then the system can be monitored using serial monitor in arduino IDE application on COM11 port. The microcontroller will automatically performs data readings through the sensor and uploads the data and displays the data upload status message on the arduino IDE serial monitor, then the time of data upload on the serial monitor (upload time from the microcontroller) compared to the time recorded in the web based monitoring application or on the web server database. The results of data uploading test that conducted during the day during active working hours obtained that the server room temperature and humidity control system developed capable to uploads data in realtime from the system microcontroller to the database server and displayed on the web based monitoring application with average difference of data sending time and data delivery time or delay of sending data from microcontroller to web server database until data displayed in web page is 0,636363636 second. From 11 times of data sending test, 5 times data successfully sent without delay, 5 times the data sending with delay 1 second and one time data sending with delay 2 second as shown in Table 3.

Table 3. Result of data uploading test from microcontroller to database server and web monitoring application

Id	Temp	Humid	Temp AC	Mode AC	Sensor Read Time Wemos D1	Data Show Time On Web	Delay (Second)
30567	31.2	69.5	18.26	DRY	2/24/2018 13:55:24	2/24/2018 13:55:24	0
30568	31.1	70	18.26	DRY	2/24/2018 13:55:07	2/24/2018 13:55:07	0
30569	31.1	69.7	18.26	DRY	2/24/2018 13:54:34	2/24/2018 13:54:34	0
30570	31.2	69.4	18.26	DRY	2/24/2018 13:54:17	2/24/2018 13:54:18	1
30571	31.1	68.9	18.26	DRY	2/24/2018 13:53:44	2/24/2018 13:53:45	1
30572	31.1	69.2	18.26	DRY	2/24/2018 13:53:27	2/24/2018 13:53:28	1
30573	31.1	69.6	18.26	DRY	2/24/2018 13:53:10	2/24/2018 13:53:10	0
30574	31.1	69.6	18.26	DRY	2/24/2018 13:52:53	2/24/2018 13:52:53	0
30575	31.1	69.6	18.26	DRY	2/24/2018 13:52:35	2/24/2018 13:52:36	1
30576	31.1	69.7	18.26	DRY	2/24/2018 13:52:18	2/24/2018 13:52:19	1
30577	31.1	70.1	18.26	DRY	2/24/2018 13:52:00	2/24/2018 13:52:02	2
Average Delay Time							0.636363636

3.4. Result of Notification Test from Web to Twitter

Twitter notification test is used to see delay time of notification sent from the web based monitoring application to twitter. we mencatat difference of notification time on the web and notification time on twitter. From the test, it is found that the system is able to send realtime notification with the average delay time 0.9 seconds as shown in Table 4 with a maximum delay time 3 seconds.

Table 4. Result of notification sending test from web monitoring aplication to twitter

Id	Notification	Data Time On Web	Data Time On Twitter	Delay (Second)
876	Warning! Temperature : 20.90 Celcius, Humidity : 49.50 %, AC Voltage : 213.50 Volt	2/24/2018 7:10:23	2/24/2018 7:10:25	2
877	Warning! Temperature : 20.90 Celcius, Humidity : 48.70 %, AC Voltage : 213.96 Volt	2/24/2018 7:25:11	2/24/2018 7:25:12	1
878	Warning! Temperature : 20.90 Celcius, Humidity : 50.90 %, AC Voltage : 212.40 Volt	2/24/2018 7:51:46	2/24/2018 7:51:46	0
879	Warning! Temperature : 20.90 Celcius, Humidity : 52.10 %, AC Voltage : 212.31 Volt	2/24/2018 8:08:22	2/24/2018 8:08:22	0
880	Warning! Temperature : 21.10 Celcius, Humidity : 60.10 %, AC Voltage : 210.18 Volt	2/24/2018 8:10:45	2/24/2018 8:10:46	1
881	Warning! Temperature : 20.90 Celcius, Humidity : 47.70 %, AC Voltage : 210.38 Volt	2/24/2018 8:21:37	2/24/2018 8:21:38	1
882	Warning! Temperature : 21.00 Celcius, Humidity : 60.20 %, AC Voltage : 209.24 Volt	2/24/2018 8:27:37	2/24/2018 8:27:38	1
883	Warning! Temperature : 21.60 Celcius, Humidity : 60.30 %, AC Voltage : 209.93 Volt	2/24/2018 8:30:44	2/24/2018 8:30:44	0
884	Warning! Temperature : 20.90 Celcius, Humidity : 47.40 %, AC Voltage : 211.33 Volt	2/24/2018 8:58:47	2/24/2018 8:58:50	3
885	Warning! Temperature : 20.90 Celcius, Humidity : 47.00 %, AC Voltage : 209.34 Volt	2/24/2018 8:59:25	2/24/2018 8:59:25	0
Average Delay Time				0.9

3.5. Result of System Speed and Effectiveness Test

At the speed test we determine the temperature and humidity to be achieved is in normal temperature 22C and normal humidity 55%. The result of the test is known that the time required from the initial temperature 26.2C to end temperature 22C takes 23 minutes. Meanwhile, to obtain humidity from 67.6 % to 55 % it need 6 minutes as shown in Figure 8 and Figure 9. In the system effectiveness test in controlling the temperature of the server room obtained the result that although the temperature value still not stable at a certain value but the system is able keeps the server room temperature in the normal range value that required for server room as shown in the graph in Figure 8 where the highest temperature is 23C, the lowest temperature is 21C and the temperature can be controlled at the desired normal value with an average temperature value 21.7905C. While on the test of system effectiveness in controlling humidity as shown in Figure 9 obtained result that during 24 hours monitoring, only happened 8 times increase of humidity with average increase of humidity 0,65%, highest humidity 61,4%, and average time until the humidity back to the normal value is 50.125 seconds with the longest time 168 seconds and the fastest 17 seconds. While the lowest humidity value is 45.9% and average humidity 52.44320017%.

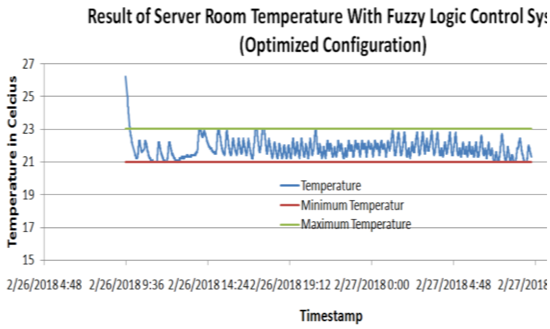

Figure 8. Result of Server Room Temperature with Optimized Configuration of Fuzzy Logic control System.

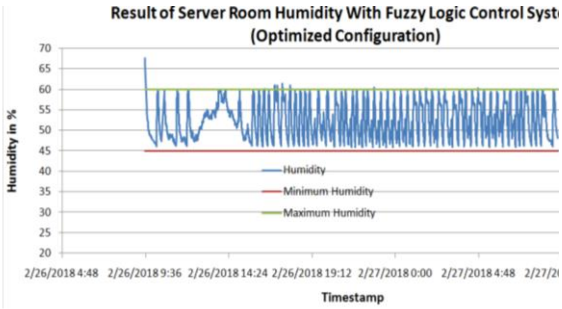

Figure 9. Result of Server Room Humidity with Optimized Configuration of Fuzzy Logic control System.

4. Conclusion

Based on results graph of the system speed and effectiveness test in Figure 8 and Figure 9 it can be concluded that the optimized system is better than previous system. Optimized system able to control the temperature from 26.2C to 22.1C within 23 minutes and able to control the humidity from 67.6% to 55.3% in 6 minutes. The system is also able to keep the temperature of the server room in the normal value range required for server room, with the highest temperature 23C, the lowest temperature 21C and the average temperature value 21,7905C. While on humidity test, it was found that system is enough to control the server room humidity in the range of normal values required. During 24 hours of monitoring, only 8 times the increase of humidity above the maximum standard of humidity, with an average increase of humidity 0.65%, the highest humidity 61.4%, and the average time until humidity return to the normal value is 50.125 seconds with the longest time 168 seconds and the fastest 17 seconds. While the lowest humidity value 45.9% and moisture average is 52.44320017%. The system is also capable to send data from the microcontroller to the web server database until the data is displayed on the web page with an average delay time 0.636363636 seconds and able to send early warning notification in realtime via twiter with average delay of sending data from web based application monitoring to twitter is 0.9 seconds.

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